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N AND S CYCLES IN CRUCIFER-LEGUME COVER CROP MIXTURES

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INTRODUCTION

Cover crops grown in rotation with cash crops provide ecosystem services by reducing pollution and anthropogenic inputs. Among cover crop families, crucifers can efficiently prevent nitrate and sulphate leaching by catching residual soil mineral nitrogen (N) and sulphur (S) to enhance N and S catch crop services (Couëdel et al., 2018a, 2018b). However, compared to legume cover crops, crucifers provide less mineralised N to the subsequent main cash crop (N green manure service). Bispecific crucifer–legume cover crop mixtures can be seen as a potential solution to increase biodiversity in cropping systems combining advantages of both species (Couëdel et al., 2018b). Nevertheless crucifers could be a poor companion crop for two main reasons: 1) they strongly compete for light, water and nutrients due to their rapid root and shoot growth and 2) they can have an allelopathic effect on legumes during their growth due to production of glucosinolates, which are exuded by roots in the rhizosphere and transformed into biocides such as isothyocianates (Matthiessen and Kirkegaard, 2006). There is a lack of information on levels of ecosystem services linked to the N and S cycles provided by mixtures compared to sole cover crops. The aim of our study was to assess the trade-offs of bispecific crucifer-legume mixtures in comparison to sole cover crops on N and S cycles.

MATERIAL AND METHODS

Experiments were conducted at two sites (near Toulouse and Orléans, France) over two years where few cultivars from eight crucifers (rape, white mustard, Indian mustard, Ethiopian mustard, turnip, turnip rape, radish and rocket) and nine legumes (Egyptian clover, crimson clover, common vetch, purple vetch, hairy vetch, pea, soya bean, faba bean, and white lupin) were tested in sole-crop and in 98 bispecific mixtures (substitutive design of 50%-50% density of sole crops). Statistical analysis was performed on four measured variables (shoots+roots): 1) N acquired, 2) S acquired, 3) N mineralised and 4) S mineralised, the N and S mineralization being calculated using respectively C:N and C:S ratios (Eriksen et al., 2004; Justes et al., 2009). Analysis of variance (ANOVA) was used to evaluate effects of site, year and cover crop type (sole crop or mixture) on each variable. Tukey test allowed distinguishing differences among cover crop types for each site-year. Statistical analyses were performed using R software (R Core Team, 2016), and differences among treatments were considered significant at $P<0.05$.

RESULTS AND DISCUSSION

Only few differences were obtained between cultivars compared. Consequently results were averaged at the species level and are presented here at the family level for highlighting the main messages.

Crucifer - legume bispecific mixtures provided the same N and S catch crop service (mean soil acquisition of 50 kg N ha^{-1} and 12 kg S ha^{-1}) and significantly increased the N green manure service (mean mineralisation of 22 kg N ha^{-1}) compared to pure crucifers (mean of 8 kg N ha^{-1}) (Couëdel et al., 2018a, 2018b). Despite half the density of crucifers, S green manure service was only reduced by 15% in the mixture (mean mineralisation of 5.5 kg S ha^{-1}) (Couëdel et al., 2018a). On a species basis, despite the high and variable competition for abiotic resources generated by crucifers, no incompatibility of growth was observed in mixtures. Overall crucifers and legumes tested were sufficiently complementary to mutualise multi-ecosystem services by providing level of each service close to that of the best sole cover crop family (Table 1).

Table 1. Services associated with nitrogen (N) and sulphur (S) cycles for crucifer and legume in sole crop (SC) or in mixture. The service is provided in proportion of the best sole crop family (average of all species tested), which then is considered at 100%.

Service	Mean crucifer SC	Mean legume SC	Mean mixtures
N catch crop	100%	66%	98%
N green manure	18%	100%	63%
S catch crop	100%	30%	99%
S green manure	100%	23%	85%

CONCLUSION

Our study confirms for a wide range of cover crop species and on four sites x years that crucifer-legume mixtures tested can provide multi-ecosystem services beyond well-known N management services. Therefore it can be recommended to diversify the species included in cover crops in order to provide a high level of multi-ecosystem services and to secure the success of cover cropping in particular for summer sowing carried out in dry regions or under low rainfall conditions.

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